Монгол Орны Газарзүй-Геоэкологи Сэтгүүл - МОГГС Mongolian Journal of Geography and Geoecology - MJGG
Дугаар 45. 2024 он Volume 45. 2024

https://doi.org/10.5564/mjgg.v61i45.3404

A study on the effect of windbreaks of forest strips established in sandy soil regions of central Mongolia

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Received: 30 April 2024 / Accepted: 15 August 2024 / Published online: 29 November 2024

ABSTRACT

The purpose of this research was to estimate the wind force reduction effects of different types of tree species in windbreak, based on monitoring results. Field experiments were carried out during 2010–2017 at the Research and Experimental Center for Combating Desertification (47°27′N, 103°68′E; 1967 m a.s.l) in Elsen Tasarkhai, Khugnu-Tarna National Park in Rashaant soum of Bulgan province, central Mongolia. The studied tree species included Acer tataricum, Populus sibirica, Malus Pallasiana, Ulmus pumila, Salix ledebouriana and Caragana arborescens. The wind data collected by the Hobo loggers were downloaded using Onset HOBOware® Lite Software Version 2.2.1 (Onset Computer Corporation, Pocasset, MA). The estimation procedure incorporated the 1999 version of the windbreak sub-model of the Wind Erosion Prediction System (WEPS). Windbreak effects were estimated in terms of friction velocity reduction, which is a function of wind speed and direction, distance from the barrier, tree height, porosity, width and orientation. Windbreak characteristics (windbreak type, height, width, porosity, and location) were recorded. A significant effect of windbreak on airflow reduction was proven on the leeward side of windbreak in a belt corresponding to approximately 15-30 times the height of the windbreaks and it depended on the optical porosity. During the monitoring period, the impacts were varied, but all species had reduced the wind speed to a certain distance. As a result, the annual growth rate of tree species showed the significant importance of wind protection. By identifying the effect of shelterbelts on living windbreaks and wind data using long-term monitoring in sandy soil regions of central Mongolia, advanced tree planting and forest strip establishing methods would be developed.

Keywords: *Tree growth, Long-term monitoring, Windbreak effect*

Төв Монголын хээрийн элсэрхэг хөрс бүхий бүс нутагт байгуулсан ойн зурвасын салхинаас хамгаалах нөлөөллийн судалгаа

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Хүлээн авсан: 2024 оны 04 сарын 30 өдөр / Зөвшөөрөгдсөн: 2024 оны 08 сарын 15 өдөр / Нийтлэгдсэн: 2024 оны 11 сарын 29 өдөр

ХУРААНГУЙ

Хамгаалалтын ойн зурвасын хийц болон мод, сөөг ургамлын төрөл зүйлээс хамаарч салхины хүчийг бууруулах нөлөөлөл хэрхэн илэрч байгаад мониторинг судалгаа явуулахад энэхүү ажлын зорилго оршино. Тус судалгааны ажлыг Хөгнө–Тарнын байгалийн цогцолбор газарт хамаарах Булган аймгийн Рашаант сумын Элсэн тасархай (47°27′N, 103°68′E; 1967 m a.s.l) хэмээх газарт байгуулсан, Цөлжилтийг сааруулах туршилт судалгааны төвийн судалгааны талбайд 2010-2017 онуудад гүйцэтгэв. Туршилтад сибирь улиас, тарваган хайлаас, тураг харгана, цагаан бургас, жимсгэнэт өрөл, татар агч зэрэг мод, сөөг ургамлыг ашигласан. Судалгааны ажлын хүрээнд HOBO U30 маркийн автомат станц суурилуулан, Onset HOBOware® Lite 2.2.1 (Onset Computer Corporation, Pocasset, MA) программ хангамж ашиглан салхины мэдээллийг цуглуулав. Ойн зурвасын нөлөөгөөр салхины үрэлтийн хүчний хурд буурах хэмжээг Салхины Элэгдлийг Урьдчилан Тооцох (WEPS) загвар ашиглан тооцсон. Ойн зурвасын хамгаалах нөлөөг салхины үрэлтийн хурдны бууралтаар тооцсон бөгөөд, энэ нь салхины хурд, чиглэл, хаалтаас алслах зай, модны өндөр, ойн зурвасын сүвэрхэг байдал, өргөн, хийц зэргээс хамаарна. Ойн зурвасын салхины хүчийг бууруулах нөлөө нь мод, сөөгийн төрөл зүйл болон зурвасын нягт, сийрэг, сиймхий байдлаас хамаарч өндрийн 15-30 дахин алслах зайд хамгаалах нөлөөлөл нь илэрч байна. Мод, сөөг ургамлын төрөл зүйлүүдийн хувьд хамгаалах нөлөө нь харилцан адилгүй илэрсэн бөгөөд, бүх төрөл зүйлүүд салхины хурдыг тодорхой хэмжээнд бууруулсан дүнтэй байна. Мөн мод, сөөг ургамлын жилийн өсөлтийн эрчим ч салхинаас хамгаалахад чухал нөлөөтэй байв. Төв Монголын хээрийн бүсийн элсэрхэг хөрс бүхий бүс нутагт, хамгаалалтын ойн зурвас байгуулан, салхинаас хамгаалах нөлөөллийг судалснаар, ирээдүйд тус бүс нутагт тарих мод, сөөг ургамлыг зөв сонгох болон хамгаалалтын ойн зурвас байгуулах дэвшилтэд арга технологиудыг нэвтрүүлэхэд чухал ач холбогдолтой ажил болсныг энд тэмдэглэх нь зүйтэй.

Түлхүүр үгс: Мод, Сөөгийн өсөлт, Урт хугацааны мониторинг, Ойн зурвасын хамгаалах нөлөөлөл

1. INTRODUCTION

One of the most traditional methods of controlling wind erosion is the establishment of windbreaks [1,2]. Windbreaks are strips of trees, shrubs or tall grass species planted around agricultural fields, houses, and animal farms to reduce the wind velocity and erosion [3,4]. Windbreaks are also referred to as wind barriers and shelterbelts [5]. The windbreaks protect soil from strong winds, divert the wind direction, and reduce wind velocity, thereby reducing soil erosion [6]. A small decline in wind velocity by adoption of control practices results in a large decrease in wind erosion [7,8]. By intercepting the erosive power of the winds, windbreaks help to improve soil properties by reducing evaporation, promoting soil water storage, and reducing losses of nutrient-rich fine soil [9].

In response to the severe dust storms of the Dust Bowl in the Great Plains of the United States in 1934, the Great Plains Shelterbelt project was implemented, which reduced soil erosion and improved the ecological conditions. The management and plan of the windbreaks varies depending on plant species, wind velocity, and soil characteristics [10]. Threshold wind speed, at which soil of the flat surface area starts to migrate, is 9.16 ms^{-1} in 15 meters above from the ground [11]. The height of the windbreaks determine the extent of reduction in wind speed, whereas width of the windbreaks determine the size of the area it shelters. Soil particles floating in the air travels 9 meters less in sheltered area [12]. The protective radius of a shelterbelt extends to a distance of 30-35 times its height in the downwind direction and 5 times its height in the upwind direction. [10,13]. Even though establishing shelterbelts is effective way to prevent from wind erosion, developing countries face difficulties when it comes to implementation [14]. 7.9 percent of Mongolian territory is covered by forest [15], and 76.9 percent is affected by desertification and land degradation to certain extent [16]. 145 settlement areas in desert and steppe zones are prone to sand migration [17], and the fact that frequency of dust and sand storm has doubled in the last decade [18,19,20,21] is garnering government's attention. To specify, main activities of the "One Billion Trees" National movement, initiated by the president, U.Khurelsukh, include establishment of shelterbelts [22,23,24,25]. Our study area is located in Khugnu Tarna protected area covering Central Mongolian steppe zone, where desertification and land degradation is at severe level. According to the literature, it is estimated that 15 percent of Khugnu Tarna protected area is degraded as of 2011, which is increased by 7 percent since 1990 [26]. The objective of this study was to identify the effects of shelterbelts comprising several tree species intended for reforestation in comparison to the yearly growth observed during the study period. The results of the study can be used as a model in geographically and spatially similar areas for the purpose of assessing the effects of shelterbelts and developing management plans. Further investigation is required in order to gain a greater understanding of the impact on microclimate and the effect on alleviating sand migration.

2. MATERIALS AND METHODS

2.1. Profiles of Windbreaks and Data Collection

The study area is situated in the transitional zone between forest-steppe and dry steppe zones, as defined by the Mongolian plant geographical classification. [27]. A total of 120 trees were used for each replicate, with each species being compared with twenty different trees. The trees were planted at a spacing of 2 x 1.5 metres. During the experiment, trees were irrigated by a drip irrigation system. Trees height growth were measured twice a year (Spring and Autumn) and each year monitoring was conducted during the last week of September. The experimental trees for each species were sampled at four (4 subplot * 5 tree) replications. The growth in height of the trees was recorded. The highest point of each tree was measured from the ground using a measuring tape with a total length of 5 metres. Root collar diameter growth were measured using a digital Vernier calipers (Mitutoyo Corporation, CD-20APX, Kawasaki, Japan). Stems were marked and numbered to allow repeated measurements at the same position on each stem. Since growth may be related to initial tree size at the beginning of the growth period, relative height growth was calculated using the following equation [28,29,30]. The survival and damage of trees were calculated as a percentage of the number of living individuals from the total number of planted trees and the number of damaged individuals from the number of survived trees, respectively. The weather data collected by the U30 Weather Station data loggers were downloaded using Onset HOBOware® Lite Software Version 2.2.1. The wind speed and wind direction, were measured every 3 seconds (s) by using the data logger with S-WSB-M003 and S-WDA-M003 sensor, located 2 meters above the surface.

2.2. Wind Erosion reduction effects of Windbreaks

The driving variable for transport is the wind friction velocity μ^* (m/s), which is related to average wind speed U(z) (m/s) at height z (m) by the logarithmic law [31]:

$$U_{(z)} = \frac{\mu^*}{k} \text{In}\left[\frac{z-d}{z_0}\right] \qquad (1)$$

Where $U_{(z)}$ is the wind velocity at height *z*, μ^* is the friction velocity, *k* is the von Karman constant equal to 0.4, *d* is the aerodynamic displacement height equal to 0.7 x height of roughness element, and z_0 is the aerodynamic roughness parameter assumed to be equal to 0.15 x height of roughness element [32]. The friction velocity is calculated in two steps [12]. First, the friction velocity at the weather station (u_*^{WS}) was computed by applying the logarithmic law (Eq. 1), then the friction velocity at the subregion level u_*^R was calculated with Lettau's equation [31]:

$$u_*^R = u_*^{WS} \left(\frac{z_0^R}{z_0^{WS}}\right)^{0.067} \qquad (2)$$

Where z_0^R is the roughness height of the subregion and z_0^{WS} is the roughness height at the weather station [12]. The friction velocity reduction (f_{xh}) of wind in m/s^{-1} by windbreaks was calculated as follows (Vigiak et al., 2003):

$$f_{xh} = 1 - \exp[-axh^2] + b\exp[-.003(xh + c)^b] \qquad (3)$$

$$a = 0.008 - 0.17\theta + 0.17\theta + 0.17\theta^{1.05} \qquad (4)$$

$$b = 1.35\exp(-0.5\,\theta^{0.2}) \qquad (5)$$

$$c = 10\,(1 - 0.5\theta) \qquad (6)$$

$$d = 3 - \theta \qquad (7)$$

$$\theta = op + 0.02\frac{w}{h} \qquad (8)$$

where *xh* is the distance to the windbreak parallel to the wind direction in barrier heights, θ is the barrier porosity, *op* is the optical porosity, w is the barrier width, and *h* is the barrier height [13]. The influence of windbreaks on soil erodibility of the sheltered fields can be estimated by [33].

$$d = 17h\left(\frac{V_m}{V}\right)\cos\theta \quad (9)$$

Where *d* is distance of full protection by the barrier in the lee (m), *h* is height of the barrier (m), V_m is minimum wind velociy at 15 m height needed to move the most erodible soil fraction, V is actual windvelocity (m/s^{-1}). And cos θ is angle of the prevailing wind direction.

2.3. STATISTICAL ANALYSIS

The comparision procedures were statistically analyzed by one-way analysis of variance (ANOVA) followed by the homogeneity of variance which was verified using Levene's test. Statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS) Version 21 (IBM Corp., New York, NY, USA). Statistical significance was accepted at $p < 0.05$.

3. RESULTS

3.1. The Wind Speed and Direction in Elsentasarkhai Station

The results show the wind speed recorded from Elsentasarkhai at an hourly resolution (2013-2017). Statistical data summarized provisional wind speed (m/s) data at daily variability resolution average, minimum, maximum, average, and gust speed of data available (Figure 1). The figure 1 showed the full record, while figure 2 showed the study years and the each seasonal data. The threshold for calculating climate statistics for the wind variables was, 95 % of data availability. The study area had a semi-arid continental climate that was characterized by average wind speed of 2.55 m/s with maximum 16.87 m/s, respectively; whereas the gust speed was with 5.41 m/s, and maximum 23.67 m/s. Seasonal patterns were evident with the strongest wind events occurring during spring and the most consistent wind speeds occurring during summer. High wind speed was usually observed during the spring season (Figure 2).

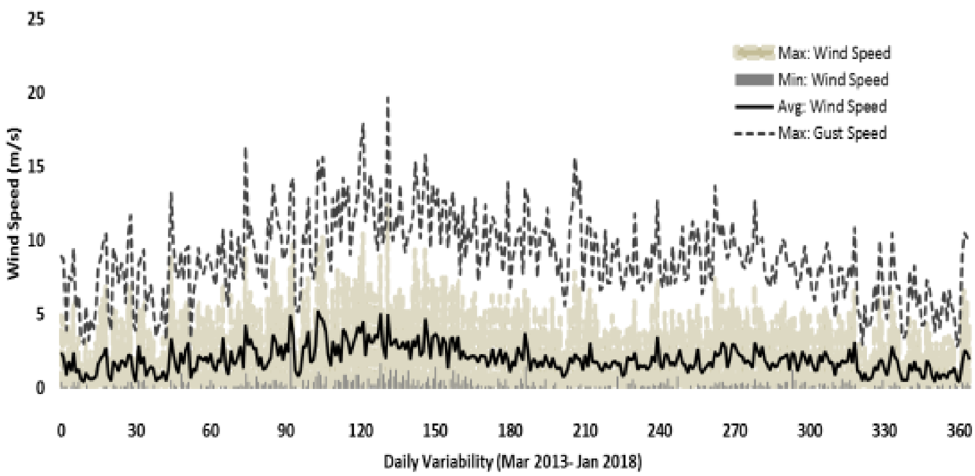

Figure 1. Elsentasarkhai: Mean daily variability of wind speeds fall within this range 95% of the time (365 days).

The frequency of wind direction in each season was displayed in Figure 3 by the wind rose. Wind direction was mainly found in the WNW-NNE and ESE–SE sectors, as a result of the orientation of the Khugnu-Tarna sand dunes. The mountains to the north (Khugnu-Khaan mountain) and south (Bat-Khaan mountain) of the Khugnu Tarna sand dunes significantly inhibited winds in these directions, especially those with a wind speed above 2 m/s^{-1}. The strongest wind direction, was about NW and NNE at this site.. However, during the winter season, the wind roses predominantly indicate wind directions from the west-north-west (WNW) and north-west (NW). The frequency of northerly winds was comparable with that of easterly or westerly winds. The wind speed of easterly winds was exclusively below 2 m/s^{-1}.

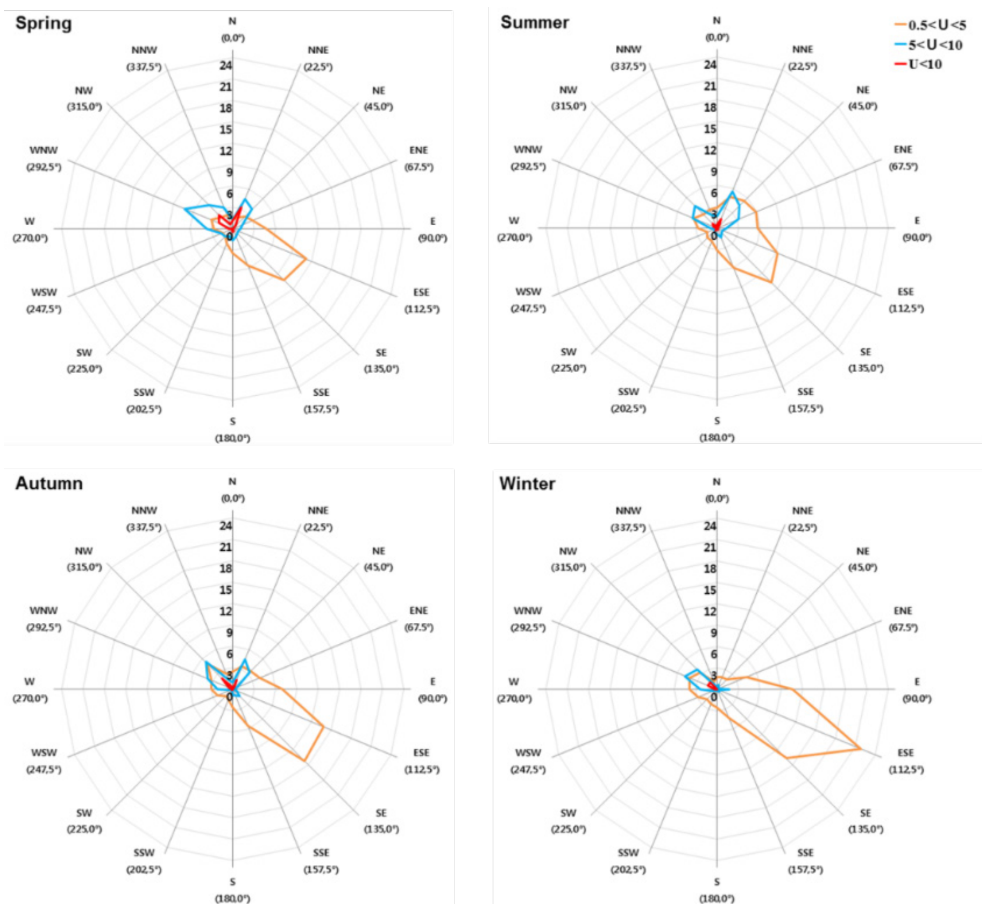

Figure 2. Elsentasarkhai; Seasonal windroses. The wind direction and speed data were divided into 16 wind direction categories (22.5° each) and 3 wind speed classes: (1) less than 5 m/s^{-1}, (2) between 5 m/s^{-1} and 10 m/s^{1}, and (3) greater than 10 m/s

3.2. Height Growth of Tree Species

The species studied showed different height growth, even though all individuals were measured under the same ecological conditions for trees and shrubs. The study showed an increase in the growth of *A. tataricum* (164.1 cm) and *P. sibirica* (276.4 cm) and root collar diameter of *A. tataricum* (35.93 mm) and *P. sibirica* (56.69 mm) until 2013. However, *A. tataricum* showed decreased growth (111.7 cm) and root collar diameter (24.61 mm) from 2014 to 2016 (Figure 3). Furthermore, the species U. pumila and C. arborescens exhibited a sustained increase in growth and root collar diameter in comparison to A. tataricum and P. sibirica. M. pallasiana exhibited a markedly slow growth rate, accompanied by notably short root collar diameter values in comparison to other species (Figure 3).

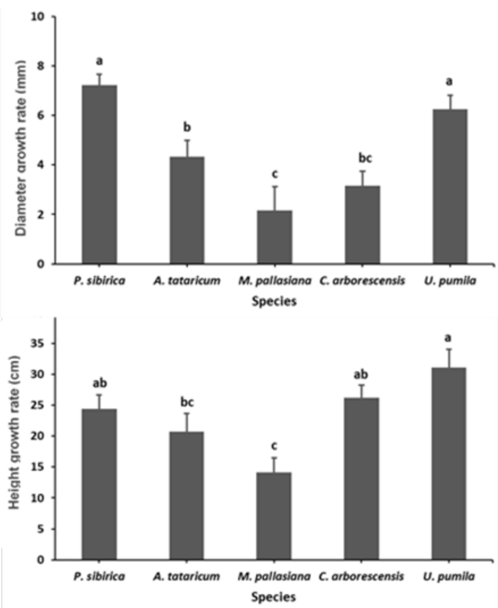

Figure 3. Comparison of height and diameter growth rates in the annual growing season of trees and shrubs. Different letters on the bars indicate significant diffrence (Dancan's Multiple Test at p = 0.05)

A comparison of the growth rate in height and diameter revealed significant differences in all growth measurements. The growth rate of *U. pumila* (31.13 cm) was observed to be the highest, followed by that of *P. sibirica* (24.45 cm) and *C. arborescens* (26.15 cm). The highest average root collar diameter was observed in *P. sibirica* and *U. pumila* (6.24 to 7.22 cm), while the lowest average root collar diameter was observed in *M. pallasiana* (2.15 cm). According to the monitoring, average growth rate of *A. tataricum* decreased since 2013. The trees species studied showed different height growths, even though all individuals were measured under the same ecological conditions . This tree growth monitoring research was carried out between 2010 to 2017. Overall, the results showed that *P. sibirica* showed the tallest tree height, after *A. tataricum*, *S. ledebouriana, U. pumila, C. arborescens*, but *M. pallasiana* species has the shortest height in autumn 2017. The height growth of *P. sibirica*, *U. pumila, C. arborescens and S. ledebouriana* significantly increased (7.02 %, 13.30 %, 30.35% and 9.14 %, respectively) during the study years. But *A. tataricum* (-1.56 %) and *M. pallasiana* (-3.70 %) species showed a decrease in height. The value of trees height showed significant differences between species ($F = 41.43$ to 79.08; $p = < 0.001$). The reason behind decrease of tree growth is due to the environment, which is not compatible with the tree species studied.

3.3. Estimated Distance of Full Protection by the Wind Break in the Leeward Side

Results showed the distance of full protection by the barrier on the leeward side at Elsentasarkhai research station during 2010–2017. The moderate linear relationship of *P. sibirica, S. ledebouriana, U. pumila, C. arborescens* was manifested at the weak linear relationship of *A. tataricum* and *M. pallasiana* (R^2 = 0.61, 0.41, 0.31, 0.43, 0.05 and 0.03, respectly).

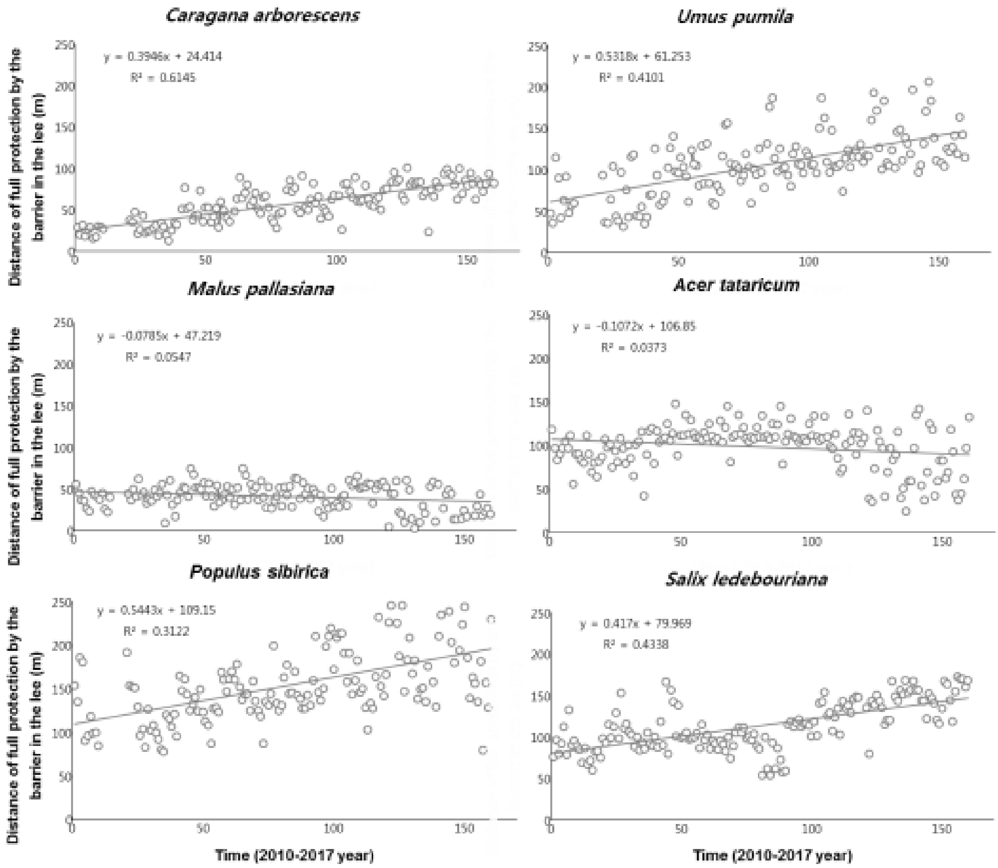

Figure 4. Windbreak effects of deciduous trees and shrubs in Elsentasarkhai station during 2010–2017

During the monitoring period, the impacts varied, but all species reduced the wind speed to a certain distance (24.58 to 193.35 m lee). In comparison to tree species, P. sibirica (6.93%), S. ledebouriana (9.07%), U. pumila (13.26%), and C. arborescens (29.93%) exhibited notable height growth and uninterrupted comprehensive protection throughout the study period. However, then *A. tataricum* (-1.48 %) and *M. pallasiana* (-3.64 %) showed significantly decreased height growth pattern, they exhibited significant windbreak effects (12.03 to 26.63 and 11.61 to 78.51 meters lee) Fig 3. The annual growth rate of tree species provides clear evidence of the significance of wind protection.

3.4. Estimation of the Friction Velocity Reduction at a Distance Relative to Tree Species

The following table 1 showed the results of estimated friction velocity reduction at a distance relative to tree species, fild measured data has been used in Elsen Tasarkhai station (2010-2017). The study demonstrated that windbreak significantly reduced the wind velocity to a distance of 5-30 times the height of windbreak on the t leeward side (F = 59.11 to 106.20; p = < 0.001).

Table 1. Relationship between distance and tree species in friction velocity reduction

Species class	Distance from the windbreak							
	0H	5H	10H	15H	20H	25H	30H	35H
Effect of reduce wind on tree species (%)								
P. sibirica	0.88	1.46[a]	1.77[a]	1.80[a]	1.79[a]	1.77[a]	1.75[a]	1.74
A. tataricum	0.88	1.01[c]	1.30[c]	1.50[c]	1.63[b]	1.70[b]	1.75[a]	1.74
M. pallasiana	0.86	0.88[d]	0.94[d]	1.02[d]	1.11[c]	1.21[c]	1.30[b]	1.70
U. pumila	0.87	1.22[b]	1.64[b]	1.78[a]	1.80[a]	1.79[a]	1.78[a]	1.74
C. arborescens	0.89	1.03[c]	1.36[c]	1.63[b]	1.76[a]	1.81[a]	1.81[a]	1.74
S. ledebouriana	0.86	1.28[c]	1.71[ab]	1.80[a]	1.79[a]	1.78[a]	1.77[a]	1.74
F	1.40	70.66	106.20	105.67	99.63	80.98	59.11	0.76
Sig.	ns	***	***	***	***	***	***	ns

Data followed by the same case letter across column are not significantly different at 0.05 level. 5H, 10H, 15H - distance from the windbreak to the stand position in 5, 10, 15 times the height of the windbreak

A comparison of the amount of friction velocity reduction demonstrated that trees of the species P. sibirica, U. pumila, and S. ledebouriana had a significantly greater precedence effect on wind speed reductions in the distance of 15-20H the leeward side. In contrast, trees of the species A. tataricum, M. pallasiana, and C. arborescens exhibited a more pronounced effect in istance of 25-30H the leeward side.The table 2 showed the results of windbreak porosity class effect in reducing wind speed on mixed tree species. The measured values significantly reduced the wind velocity for a distance of 15-30H the windbreak height in the leeward side (F = 3.70 to 25.06; p = < 0.05).

Table 2. Relationship between distance and porosity class in friction velocity reduction

Porosity class	Distance from the windbreak							
	0H	5H	10H	15H	20H	25H	**30H**	**35H**
Porosity class effect of reduce wind on mixed tree species								
20%	0.94	1.48	1.78	1.81[a]	1.80[a]	1.78[a]	1.76[a]	1.74
40%	0.90	1.44	1.75	1.78[b]	1.78[b]	1.76[ab]	1.75[ab]	1.73
60%	0.87	1.45	1.74	1.77[b]	1.76[c]	1.75[bc]	1.74[bc]	1.72
80%	0.82	1.50	1.74	1.76[b]	1.75[d]	1.74[c]	1.73[d]	1.72
F	2.49	0.39	0.69	6.44	25.06	9.55	3.70	1.33
Sig.	ns	ns	ns	**	***	***	**	ns

Data followed by the same case letter across column are not significantly different at 0.05 level. 5H, 10H, 15H – distance from the windbreak to the stand position in 5, 10, 15 times the height of the windbreak

The effects of wind friction velocity in the porosity class order of 20, 40, 60, and 80 % have been found to be reduced.

According to the comparative study, the significantly higher friction velocity was reduced to 15-20H on the leeward side with a porosity of 20-80 % on mixed trees.

4. DISCUSSION

The findings from this study suggested that it was characterized by average wind speed of 2.55 with maximum 16.87 m/s, respectively; whereas the gust speed was 5.41, with maximum 23.67 m/s (Figure 1). The wind velocity must be near 8 m/s^{-1} at 2 meters above the soil surface for the soil particles to be displaced by wind [34]. Sandy loam and sandy soils with low organic matter content develop aggregates with weak bonds and were thus the most erodible. Dry loose soil material <0.84 mm in diameter occurring on the soil surface, known as loose erodible material, was the fraction that was readily transported by wind [35]. The way that wind speed and turbulent flow were modified by the windbreak will determine its shelter efficiency [36].

According to these findings, there was a high risk of wind erosion in the study area. This study presented to identify the effects of shelterbelts consisting of several tree species intended for reforestation in comparison to yearly growth observed during the study period. Windbreak studies have been particularly useful for determining relationships between height, width, porosity and species type of windbreak elements [37,38]. The full protection by the barrier on the leeward side to moderate linear relationship of *P. sibirica, S. ledebouriana, U. pumila, C. arborescens* was manifested at the weak linear relationship of *A. tataricum and M. pallasiana* species. But then *A. tataricum* and *M. pallasiana* have significantly decreased height growth pattern, but have been shown to have significant windbreak effects.

The following friction velocity reduction at a distance relative to tree species, where windbreak significantly reduced the wind velocity for a distance of 5-30H of the windbreak height on the leeward side. This study shows the amount of friction velocity reduction, *P. sibirica*, *U. pumila,* and *S. ledebouriana* trees had the significantly precedence effect on wind speed reductions in distance of 15-20H on leeward side, while *A. tataricum*, *M. pallasiana* and *C. arborescens* had better effects at the distance of 25-30H on leeward side. In a related study, the windbreak consisting of short trees demonstrated more pronounced deceleration than the tall trees, due to their lower porosity in general, which supported previous findings that low-porosity elements induced the greatest deceleration . An evaluation of the sheltering effects of the windbreak was deemed appropriate in accordance with whether the leeward wind speed exceeded the critical value or not [39]. These and other confounding factors indicate that previous interpretations of Naegeli's results have overstated the correlation between porosity and sheltered area [40]. A detailed examination of the of results from other field measurements failed to reveal any significant differences in the sheltered area for low and high porosity windbreaks [5]. In other related studies, wind tunnel studies have not find significant reductions in low porosity windbreaks [41].

In the present study, was windbreak porosity class effect of significantly reduced the wind velocity for a distance of 15-30H the windbreak height in the leeward side. In comparision, there is friction velocity reduced significantly 15-20H of leeward side which porosity of 20-80 % on mixed trees. Other related experimental studies showed that wind speed was reduced by 62% in open wind speed, but the estimated erosive force of the wind was reduced to 24 % of open values [42]. Multiple row-windbreaks reduce wind erosion more than single rows [34]. The results of this study were demonstrated that even a small reduction ratio of wind speed could effectively reduce the erosive force of the wind and therefore help control wind erosion particularly if windward protection is considered [43]. In our experiment, the impacts have been varied, but all species have reduced the wind speed to a certain distance. Consequently, the annual growth of tree species demonstrated the significance of wind protection. Once a windreak has been established, it will have a sustained and long-lasting positive impact on the environment. Further studies and experiments will be required to be undertaken based on the results of this study in different ecological zones in order to ascertain the most effective means of reducing land degradation.

5. CONCLUSIONS

The purpose of this research is to estimate wind force reduction effects of windbreak comprising different tree species based on empirical experiments. The full protection provided by the barrier on the leeward direction to moderate linear relationship of *P. sibirica, S. ledebouriana, U. pumila* and *C. arborescens* was manifested at the weak linear relationship of *A. tataricum and M. pallasiana* species. But, *A. tataricum* and *M. pallasiana* have significantly decreased height growth patterns, and have been shown to have significant windbreak effects.

The following reduction in friction velocity relative to mixed tree species was observed: the windbreak significantly reduced the wind velocity for a distances of 5-30 times the height of the windbreak on the leeward side. This study showed the amount of friction velocity reduction *P. sibirica*, *U. pumila,* and *S. ledebouriana* trees had, the significantly precedence effect on wind speed reductions in 15-20 times of leeward side, while *A. tataricum*, *M. pallasiana* and *C. arborescens* had better effect on 25-30 times leeward. The short shrubs tended to produce a more intense deceleration than the tall trees, due to their lower porosity in general, which supported previous findings that low-porosity elements induced the greatest deceleration. During the monitoring period, the impacts have varied, but all species have reduced the wind speed to a certain distance. As a result, the annual growth rate of tree species showed the significance of wind protection

ACKNOWLEDGMENTS

This study was supported by the Center for Combating Desertification in Arid and Semi-arid Areas, Republic of Korea and Division for Desertification Study at the Institute of Geography & geoecology, Mongolian Academy of Sciences.

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